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Statement of

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Plan
Before the
Subcommittee on Manned Space Flight
Committee on Science and Astronautics
House of Representatives

Mr. Chairman and Members of the Subcommittee:

I appreciate the opportunity to discuss with you the status and plans for the Saturn launch vehicles. In my discussion, I will also cover present status of the F-1 engine development program.

Status and plans for the Saturn vehicles cover a good deal of ground. We have, to begin with, development programs for five stages, two instrument units, and four major engines. There is also the required complex of ground test, manufacturing, and launch facilities, together with appropriate ground support equipment. We must also consider the various interfaces involved: stage-to-stage, spacecraft to vehicle, and vehicle to facilities. And that very large interface of government to industry, which is critical in getting these complex and demanding programs to work as parts of a coordinated whole.

The managerial requirements of these programs are fully as arduous as the scientific and technological requirements.

As managers, we have to spend the taxpayers' money as carefully and intelligently as possible, and get the most out of what we spend. To do

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this, we keep ourselves keyed up to a high level of technical competence. We must remain in a position where we can establish standards and evaluate proposals. And we must retain and nurture the ability to act effectively, in all aspects of exceedingly technical programs, to stop trouble before it starts.

This is bench-oriented philosophy; the position of strength from which management leads in new programs where we are working up the technology as we go along.

With this preface, let me turn, now, to the development programs for the SATURN I, IB, and V. About two weeks ago, Brainerd Holmes gave you an overall view of these programs as they are integrated into the total manned flight effort. From this account, I would like to step off into a more detailed review of the launch vehicle programs and where we are today.

SATURN-CLASS LAUNCH VEHICLES

There are three Saturn vehicles being developed to support the Apollo phases of the manned flight programs. SATURN I, now in flight testing, is to be a two-stage vehicle capable of placing about 11 tons into earth orbit. The vehicle will place two of the three Apollo modules into orbit for flight testing and spacecraft qualification.

The SATURN IB is an intermediate step between the present SATURN I and the SATURN V, and draws a stage from each of these programs. By combining the flight-tested SATURN I first stage with an advanced upper stage from the SATURN V, we will secure a vehicle with a payload capability

of about 16 tons. The vehicle will launch the complete Apollo spacecraft into low earth orbit for qualification of the Lunar Excursion Module and development of spacecraft orbital maneuvers.

The final Saturn vehicle is the three-stage SATURN V, being developed to support the manned lunar mission, including both circumlunar flights and manned lunar landings. The SATURN V will have an earth orbital capability of about 120 tons, and it will be able to accelerate 45 tons into an earth-lunar trajectory.

This summary is indicative of the role played by each vehicle in supporting development of the Apollo spacecraft system. Of equal importance are the technological advances secured during these development programs which lead to the rapid definition and development of the SATURN V vehicle system and associated equipment. The technological enrichment occurs at virtually every level of vehicle development: from propulsion systems and the application of liquid hydrogen technology, through vehicle structures, guidance and instrumentation, and propellant tank manufacturing methods, to ground and flight test philosophies.

SATURN I

Development of the first of the Saturn heavy launch vehicles began in 1958. This vehicle, SATURN I, is now undergoing flight tests, with ten launches scheduled during the development program. The first four vehicles use live first stages, only, with inert upper stages. The remaining six vehicles will be composed of live first and second stages (Slide 1). By

1965, we expect to have an operational SATURN I with the capability of orbiting about eleven tons of payload. With this capability, we can place two of the three Apollo modules into a low-earth orbit to begin qualification of these modules and crew training. These two modules are the command module and a partially fueled service module. We expect to begin this training program in 1965, with the first manned flight. During prior flights, we will have flown unmanned but instrumented modules to add confidence and reliability for manned flights.

SATURN I FIRST STAGE

Eight of the ten R&D first stages are being built by the Marshall Space Flight Center at Huntsville, Alabama. Chrysler Corporation Space Division is building the remaining stages at the government-owned Michoud plant in New Orleans.

In February, NASA Headquarters approved negotiations to modify the contract awarded Chrysler Corporation in July, 1962, for the manufacture of the Marshall-developed SATURN I boosters. The modified contract will call for a total of 20 boosters; 8 S-I and 12 S-IB (the SATURN IB first stage). Delivery is to be made between 1964 and 1967.

The two-stage SATURN I flight booster is approximately 21.5 feet in diameter and 80 feet in length (Slide 2). It is powered by eight H-1 engines burning LOX/kerosene propellants. The engines, produced at Rocketdyne's Neosho, Missouri plant, were rated at 165,000 pounds thrust for the first 4 test flights. The engines have been tested satis-

factorily at the design thrust level of 188,000 pounds and will be used for the SA-5 and subsequent flight boosters. A thrust of 1.5 million pounds is delivered by the combined eight engines. Vehicle tanks have been lengthened to accommodate 850,000 pounds of propellant, 100,000 pounds more than that of the earlier booster. Guidance, control, and related instrumentation have been relocated to an instrument unit forward of the second stage, and fins added to augment the dynamic stability of the man-rated vehicle.

The first of these modified SATURN I boosters, S-I-5, has been assembled at Marshall, and the final static firing qualification tests are to be completed this month. During the tests, a total of 1.5 million pounds of thrust was developed. This will then be the first flight booster to fly with full-rated stage thrust. The booster will be delivered to the Cape in June of this year.

Also at Marshall, assembly of the first stages for SATURN I vehicles SA-6, SA-7, and SA-9 continues on schedule. (Slide 3)

At the Michoud plant, the first Chrysler-built booster for vehicle SA-8 is in production (Slide 4). Clustering of the tanks is expected to begin on schedule in May. Fabrication of the second Chrysler-built booster, is also on schedule with clustering of the tanks to begin in August. Fabrication of the first SATURN I booster (S-I-111) for manned flights is to begin at Michoud this April.

SATURN I SECOND STAGE

The second stages for SATURN I, called the S-IV, are being built by the Douglas Aircraft Corporation, Santa Monica, California. The contract with Douglas, approved in July 1960, covered procurement of 4 test stages and 9 flight stages. A proposal is now being prepared for procurement and launch support of 3 additional flight stages.

The S-IV, is 220 inches in diameter and 41 feet long. (Slide 5) Six RL10A-3 engines, developing a total thrust of 90,000 pounds, power the stage. The LOX and liquid-hydrogen burning engine will be flight tested for the first time on the SA-5 vehicle. The RL10A-3 preliminary flight rating tests were completed in mid-1962. The engine will complete qualification testing by the end of the year. Pratt and Whitney produces the engine in East Hartford, Connecticut, and tests them at their West Palm Beach, Florida plant.

The first live S-IV stage will be flight tested on SA-5. Assembly of this stage has been hampered by late delivery of parts. However, steps have been taken to correct the deficiencies; and we do not expect to have parts shortages for subsequent vehicles.

Fabrication of second stages for the remaining R&D vehicles is on schedule at Douglas. (Slide 6) In late December, the contractor began parts fabrication of the S-IV stage for the first man-rated, operational SATURN I (SA-111). Work is continuing on schedule.

SATURN I TEST VEHICLES

The ground test programs comprise a particularly critical phase of stage and vehicle development. Ground test is our best chance to evaluate designs before they become flight hardware. It is here that we develop necessary handling techniques and secure masses of data on stage operational characteristics prior to actual flight. On the ground, we can stop and start at will. We can re-instrument and re-evaluate. None of this is practical after the stage is lighted. It goes, then. There is no recall.

So, for a flight program with a minimum number of surprises, we have an intensive and detailed ground test program. This has been our approach in the S-I stage development. Test and test and test. It is more effective -- and a lot cheaper -- to ground test than to second guess a flight that did not work out the way it should have.

Now, in the test programs for the S-IV stage, at Sacramento, Marshall, and the Cape, you can see a great deal of this test philosophy in action.

Since last August, we have been testing an S-IV Battleship vehicle at the Douglas' Sacramento test facility (Slide 7). "Battleship" refers to the thick walls of the propellant tankage which are considerably heavier than a flight stage. The Battleship vehicle is the focal point for propulsion system testing. The first series of S-IV Battleship tests were completed in November, last year. During these tests, the six liquid-hydrogen engines were repeatedly fired. These tests also served to qualify the static test stand, which is a complex piece of equipment with unique

design features. Because the S-IV engines will operate in a near vacuum, the stand simulates stage operational altitude: The first firing with operational flight-type engines was successfully completed this January with a full duration of 468 seconds. These Battleship tests will continue through April.

Tests of the S-IV All-Systems vehicle will also be conducted at Sacramento. The All-Systems is a ground test stage equipped with flight-type, flight-weight systems. The tests will verify results of the Battleship test program and allow extensive engineering evaluation of the flight configuration performance. The All-Systems vehicle was completed at Douglas last December and has since been erected at Sacramento. Testing will begin later this month.

Other S-IV stage ground test programs are proceeding as scheduled. In late November, Marshall received an S-IV test vehicle (Slide 8) that is now being used in early dynamics testing of the two-stage SATURN I vehicle design. By mid-year, we expect to begin dynamics testing of the two-stage vehicle with Apollo boilerplate modules. The S-IV Dynamics vehicle was the first of the stages to be shipped from the Douglas California facility. A few weeks later, a second ground-test stage (Slide 9) was shipped from Douglas to Cape Canaveral to check out propellant systems at Launch Complex 37B. This is in preparation for the first two-stage flight later this year.

SATURN I INSTRUMENT UNIT

The SATURN I vehicle instrument unit, is being developed in-house at Marshall, with guidance, control and related instrumentation being built by industry. (Slide 10) The unit is a non-propulsive, cylindrical structure located above the S-IV stage. This unit, 154 inches in diameter, houses the vehicle guidance and control systems, telemetering and measuring equipment, and associated electrical systems. We are progressing satisfactorily in the assembly and inspection of instrument units for the SA-5, SA-6, and SA-7 vehicles. Fabrication and assembly of major guidance components and instrumentation is being performed by Bendix, Sperry, and IBM.

SATURN I LAUNCH PLANS AND MISSIONS

Three R&D SATURN I vehicles of our early design have been successfully launched from Cape Canaveral. The fourth vehicle was shipped from Marshall in January, and is now on the pad undergoing checkout for launch. The primary missions of these vehicles are to test the propulsion system, to verify the aerodynamic structural design of the first stage, and to insure that the interrelating components and sub-systems operate properly in the true flight environment. Some of the secondary missions are a test of first stage retro-rockets, a test of heat-shield insulation, and early inboard engine cutoff.

Launch of the SA-5, first of the two-stage vehicles, is scheduled for this fall. Primary flight missions are test of the redesigned man-rated booster, described earlier, test of the live second stage, performance

of the instrument unit, and interaction of all components and subsystems during flight.

With the launch of SA-6, in the last quarter of this year, we will flight test an early Apollo spacecraft configuration for the first time. The SA-8 and SA-9 vehicles will carry an additional experiment, a micrometeoroid detection satellite. (Slide 11) The satellite will collect information concerning the hazards of penetration by micrometeoroids during space flight. The data will be used for the design of manned spacecraft systems. A contract was awarded to Fairchild Stratos Corporation, Hagerstown, Maryland, in February to build three of these satellites, one as back-up. The contract calls for the satellites to be available for launch next year.

SATURN I FACILITIES

The Michoud plant at New Orleans, Louisiana, was selected in late 1961 as the manufacturing site for the SATURN I, IB, and SATURN V first stages. Renovation and modification have been underway for about a year and a half.

Shown here is the Chrysler area, which comprises about forty percent of the present plant. (Slide 12) Major tooling for fabrication of S-I stage assemblies has been installed. Fabrication work is proceeding on the first stages for both the SA-8 and SA-10 flight vehicles. All 70-inch and the 105-inch propellant tanks for the S-I-8 have been received from the

vendor and work is proceeding, on schedule, toward start of clustering in May. Build-up of the Chrysler fabrication and assembly areas will continue, concurrent with facility design which is proceeding on schedule. Complete activation is scheduled by the end of the year.

I shall cover the Boeing Michoud activities during the SATURN V portion of my discussion.

Activation of the computer facility, located at Slidell, Louisiana, is progressing satisfactorily. This facility, situated about mid-way between the Michoud plant and the Mississippi Test Operations, will support the engineering computations required at both places. By the end of March, the facility will be operational.

Construction of contractor facilities for production and test of the S-IV stage at Sacramento (Slide 13) and Santa Monica was begun shortly after award of the contract in 1960. All Sacramento S-IV facilities are now operational.

Development flights of SATURN I vehicles will be divided between Launch Complex 34 and 37B, (Slide 14). Following flight of the fourth SATURN I vehicle, final modifications will be completed at Launch Complex 34 for two-stage SATURN I launches. The modified facility will be operationally ready in the last quarter of this year.

The first two-stage SATURN I launches will be performed at Launch Complex 37B, located north of the present launch complex. Construction

is on schedule. All elements of the facility needed to support the fifth flight vehicle are scheduled for availability in June.

SATURN IB

As I mentioned earlier, the SATURN I will be able to place about eleven tons into low earth orbit. For Apollo application, the payload would comprise a Command Module and a partially-fueled Service Module. However, a vehicle of increased capability is required to place the complete Apollo, including a partially fueled Lunar Excursion Module, into earth orbit.

To support these flight missions, we are developing the SATURN IB, a two-stage liquid-propellant launch vehicle system (Slide 15). The SATURN IB is a natural fall-out of stages from both the SATURN I and V for potential high-payload applications. Essentially, the vehicle will be a SATURN I with a new second stage. That stage, identified as the S-IVB, will also be used, with slight modification, as the third stage of the SATURN V. Vehicle guidance will be all-inertial, using components qualified during SATURN I flights, and including an instrument unit similar to that to be used in the SATURN V. Development costs for both stages and the instrument unit are primarily carried by the SATURN I and V programs. By applying the results of development programs already begun, we can secure, at minimum development cost, a vehicle capable of supporting advanced Apollo earth-orbital missions almost a year prior to availability of the SATURN V.

A series of 12 launches are planned. The first four flights will be vehicle development tests, beginning in 1965 and ending in 1966. All development flights will use live first and second stages. The four development flights will carry unmanned developmental Apollo spacecraft modules. However, the flights are primarily concerned with qualification of the S-IVB stage, instrument unit, and overall vehicle.

Beginning in 1966, eight operational manned flights will be performed. All three Apollo modules will be launched into earth orbit, with a partial fuel supply in the Service and Lunar Excursion Modules. During these flights, the spacecraft crew will develop operational methods for deployment and docking of the Lunar Excursion Module, and will further define spacecraft orbital maneuver techniques. By the conclusion of operational SATURN IB flights, we will have fully tested, in earth orbit, a large portion of the system required for the lunar mission.

I should now like to comment briefly on the stages of the SATURN IB.

SATURN IB FIRST STAGE

The first stage, the S-IB, is similar to the SATURN I first stage. (Slide 16). Increased vehicle payload requirements made a slight weight reduction necessary, and it has been found desirable to incorporate a few other design features, based on our SATURN I flight experience. The stage will weigh about 16,000 pounds less. The propellant containers and the tail section assembly are being re-sized. Interstage requirements between

the S-IB/S-IVB have been defined and, last month, design of the inter-stage shroud was selected. Chrysler, contractor for the stage, was authorized last year to begin design effort. The required redesign is scheduled for completion by mid-1964.

SATURN IB SECOND STAGE

The S-IVB stage (Slide 16) is under development by the Douglas Aircraft Corporation, and is being designed for common use with the SATURN IB and V vehicles. The stage will measure almost 22 feet in diameter and 59 feet high. Liquid oxygen and liquid hydrogen are used as propellants, and the stage draws heavily on the liquid hydrogen stage experience gained by Douglas during the S-IV development program. A single J-2 engine will provide 200,000 pounds of thrust under vacuum conditions. The J-2 will also be used on the S-II, the second stage of the SATURN V.

The J-2 engine has been under development by Rocketdyne for slightly over 30 months. The first long duration, full-thrust firing was performed in October last year. Preliminary Flight Rating Tests will begin in the third quarter of this year. Engine qualification tests are to begin in about two years.

Stage design is proceeding on schedule. Fabrication of major tooling is already under way, with completion expected late this year. Vendors have been selected for development of the two basic attitude control engines required for auxiliary stage propulsion.

Fabrication of parts began last December for the S-IVB Battleship stage. This will be used at the Sacramento test facility to prove out the stage propulsion system and test site facilities for propellant handling and loading. Battleship testing is to begin during the first quarter of next year. Design of other ground test and flight stages is continuing on schedule.

SATURN IB INSTRUMENT UNIT

The instrument unit, under Marshall development, is located immediately behind the spacecraft. It will be a cylinder 36 inches high and 260 inches wide, and will contain vehicle guidance and control instrumentation, instrumentation for telemetry and tracking purposes, and associated power and electronics systems. Guidance components are now under development by Bendix and IBM, with designs to be completed by the fourth quarter this year. Flights of the vehicle stable platform are already being performed on SATURN I flights. The instrument unit is being funded from the SATURN V development effort.

SATURN IB FACILITIES

At the Douglas Sacramento Test Facility, a new test complex, is being constructed for ground test of S-IVB Battleship and flight stages under simulated operational flight conditions. (Slide 18) Site preparation was completed early this year. Construction contracts are to be awarded this month. Three test positions will be built at SACTO for Battleship, All-Systems, and flight vehicle acceptance. Development of design criteria for this latter facility is to begin next month, with construction to be completed late in 1964. Construction of the Douglas Huntington Beach Facility began early this year. The facility will be used for S-IVB final assembly and checkout, and will be ready to begin operations in October of this year.

Development flights of the SATURN IB will be launched from the Atlantic Missile Range, using Launch Complexes 37A and 37B. Construction of Launch Complex 37A, scheduled for completion early in May, is slightly ahead of schedule. The service structure, which will service both the A and B complex, will be completed about the end of this quarter. The Launch Complex 37B will be used for both the SATURN I and IB launches.

SATURN V

To place the Apollo spacecraft into an earth-lunar trajectory, we require a vehicle of far greater performance and technical sophistication than is provided by the SATURN IB. To escape from the earth's gravitational field, the spacecraft must be accelerated to an escape velocity

of 25,000 miles per hour.

To support this flight mission, we have begun development of the three-stage SATURN V. Here you see the SATURN V, a liquid-propelled vehicle capable of orbiting about 120 tons or escaping 45 tons toward the moon. (Slide 19) It will be inertially guided by components carried in an instrument unit mounted above the third stage. Vehicle development was approved in January 1962, with the mission of supporting manned circumlunar flights and manned lunar landings.

Within five years from development approval, the first SATURN V R&D flight vehicle will be launched from Launch Complex 39 at Cape Canaveral. The vehicle will consist of a live first stage, two inert upper stages, and an unmanned developmental spacecraft. The flight will test the first-stage propulsion system, and the vehicle structure and control system.

The next two vehicles are scheduled to be launched during the same year. The second flight will use a live second stage. The flight mission will include S-IC/S-II separation, test of the second-stage propulsion system and performance, as well as another test of the first stage. The third flight vehicle will carry three live stages. The spacecraft carried by this vehicle will be subjected to the complete launch exit environments. Spacecraft experiments, such as high-speed re-entry, will begin with the fourth launch.

The first manned flight with the SATURN V will occur with the seventh

launch, presently scheduled during 1967.

SATURN V FIRST STAGE

This slide illustrates the S-IC stage (Slide 20). It is 33 feet in diameter and 138 feet long. The initial thrust for the six million-pound SATURN V will be generated by five Rocketdyne F-1 engines burning LOX and kerosene. The combined thrust of these engines is 7.5 million pounds at sea level.

Stage design work is being performed as a combined effort by Marshall and Boeing personnel. Tooling fabrication and some component design is being performed by Boeing at their facility in Wichita. Three of the ground test stages and the first flight stage will be assembled at Marshall. The other 10 stages called for in the contract, which was signed about two weeks ago, will be produced by Boeing at the Michoud plant in New Orleans, Louisiana. This phasing will allow the fastest possible stage development and production, coupled with optimum transfer of experience gained by Marshall in vehicle development.

Preliminary stage design and layout were completed late last year. At the present time, engineering design for production is on schedule, and engineering tests are being performed now.

The S-IC tooling build-up at Marshall started late last year and is progressing satisfactorily. Here you see one of the bulkhead tools installed at Marshall (Slide 21). The tools and fixtures were fabricated by Boeing at their Wichita, Kansas plant.

Last month, Boeing began fabricating fuel tank segments at Wichita.

These segments will be shipped to Marshall for use in early buildup of a ground test stage.

At the Michoud plant in New Orleans, production build-up is continuing. This 40-foot boring mill (Slide 22) has already been used by Boeing to fabricate the first Y-ring, a two-ton structural element of stage tankage. The Y-ring has been received by Marshall, and we will use it to qualify some of our tooling.

The first Boeing-produced stage, a ground test vehicle, is scheduled to roll out the Michoud doors in late Spring 1965.

SATURN V SECOND STAGE

The SATURN V second stage called the S-II, is shown here (Slide 22). It is 33 feet in diameter and 81 feet long. The stage is powered by five Rocketdyne J-2 engines producing a combined thrust of one million pounds under vacuum conditions.

The design, production, and test of this stage is being performed by the Space and Information Systems Division of North American Aviation, Inc., Downey, California. A preliminary S-II contract was awarded to the Space and Information Division in September 1961. On October 12, 1962, NASA approved the S-II stage definitive contract, which calls for 5 ground test stages and 9 live flight stages. Delivery of the first live flight stage is scheduled April 1966.

At the present time, engineering design is on schedule. Space and Information Division completed the preliminary stage criteria and layout

the middle of last summer. Engineering testing, mostly with models, is progressing satisfactorily.

One of the engineering models being used by Space and Information Division, is shown in this slide (Slide 23). It is a full-scale bulk-head mock-up. Among other things, it is being used to determine a satisfactory method for the bulkhead fabrication.

Stage tooling is being produced by the North American Los Angeles Division and is being installed in the government-owned Seal Beach assembly facility.

Space and Information Division has begun the fabrication of S-II Battleship stage components and should begin live ground firing tests in mid-1964. Fabrication of the All-Systems stage will start in mid-1963. It will be placed in the All-Systems test stand at Santa Susana, California, during the first quarter of 1965.

SATURN V THIRD STAGE

I have already covered the SATURN V third, or S-IVB, stage (Slide 24). So I will limit my remarks to the S-IVB as it relates to the SATURN V vehicle.

The contract for the design, production and test of the Saturn S-IVB stage was awarded to the Douglas Aircraft Company last August. The contract which is now being modified will require a total of five ground test stages and ten flight stages for the SATURN V and four flight stages for the SATURN IB.

The instrument unit for the SATURN V will be carried directly above the S-IVB. As I mentioned earlier, the unit is being designed and built by Marshall for both the SATURN IB and the SATURN V. Design and engineering for the unit is on schedule. It will be completed late in 1963 and will be followed by a test program beginning in early 1964.

SATURN V FACILITIES

The size of SATURN V stages has presented us with the problem of providing facilities large enough to build and test them. We have modified existing facilities where possible. Where it was not possible, we have begun construction of new facilities.

At Marshall, construction and modification is proceeding satisfactorily. Here you see an artist's concept of one of the facilities under construction at Marshall, the S-IC static test stand (Slide 26). The stand foundation, which extends about 35 feet below ground surface, was completed last December. Construction of the 420-foot high superstructure started immediately after foundation completion. By August 1964, the first S-IC static firing will be performed in this stand.

Here is another test facility to be built at Marshall, the SATURN V dynamics test stand (Slide 27). In this stand, beginning in April 1965, we will test a complete three-stage SATURN V vehicle for response to simulated flight environment, including vibration levels, body bending modes, and other dynamic criteria. Design of this stand was completed a few weeks ago and the construction contract has just been awarded. It will be completed by mid-1964.

Construction and modification at our Michoud plant are proceeding on schedule (Slide 28). By early 1964, the S-IC portion of the plant should be completely activated. Tooling is now being procured.

The major construction effort at Michoud is the Vertical Assembly Building, shown on the right-hand side of the slide. This structure,

over 200 feet high, will, when finished in November of this year, be used to assemble and hydrostatically test S-IC stages.

The stages produced at Michoud will be static tested at the Mississippi Test Operations, about 39 miles east of Michoud, and the S-II stage will later be acceptance tested at this site (Slide 29).

Most of the 13,500 acres, which the government is acquiring outright, has been obtained. Easements are being secured on the surrounding 128,000 acre buffer zone. This outer area can be used for farming or grazing, but will not be open to habitation because of the high-level noise and vibrations caused by the firings.

Design criteria for the test facility were completed just a few days ago. We are on schedule, and have reached the point where the people in this area will begin to see dirt being moved and buildings being constructed.

Construction is proceeding on schedule at other SATURN facilities. The S-II bulkhead fabrication building at the Seal Beach assembly and test facility is nearing completion (Slide 30). Last month, the Space and Information Division began installing the first fabrication tooling in this building. Construction at Seal Beach started early last September. Work on the other buildings shown in the slide is well under way, and the facility should be activated early in 1964. The S-II high-energy forming production facility at El Toro, California, has been completed. Construction at the Santa Susana static test area is also on schedule,

and the facility should be completely activated by November 1963.

At Cape Canaveral, site preparation for the SATURN V Launch Complex 39 is progressing satisfactorily (Slide 31). The ground is being cleared and design criteria for the vertical assembly building were completed last December. Drawings and specifications should be completed by next August.

This concludes my summary review on the status and plans for the SATURN programs. I would now like to address myself specifically to the status and plans for the F-1 Engine program.

F-1 ENGINE

Description (Figure 32)

The F-1 Engine is the largest liquid propellant engine in the free world. A single engine produces 1 1/2 million pounds of thrust. To obtain this level of thrust, three tons of kerosene fuel and liquid oxygen are pumped into the thrust chamber every second, using a turbopump on the engine which develops 60,000 horsepower. The engine is 13 feet across at the exit and stands 18 feet high. It weighs ten tons.

We have used in this engine the same basic design principles as those used in prior liquid rocket engines, such as the Redstone, Thor, Jupiter, and SATURN I. The propellants used are the same as on those engines. At the same time, however, we have found it possible to make improvements and simplifications based on our prior experience.

Program History

The initial studies for the F-1 Engine were performed in 1958. They showed that an engine of this size would be feasible to design and build. The contract for development was signed with the Rocketdyne Division of North American Aviation in January of 1959. Shortly after establishment of the Marshall Space Flight Center as a part of NASA, the technical management responsibility was transferred from NASA Headquarters to the Center. Since that time, a number of research and development engines have been built and a total of 266 test firings have been made. In the early part of the program engine systems testing was aimed at determining the inter-action of components during the critical start transition phase of operation. Consequently, most tests were of short duration.

Facilities

The testing of the F-1 Engine requires the use of large test facilities. Concurrent with the engine development program, work was pursued on the design and construction of the largest engine test facilities in the country. These test stands are located in the Mojave Desert in California, at Edwards Air Force Base. Because of the size of the stands, a major development effort was necessary to obtain the test equipment for use on these stands. For example, the valves in the propellant lines supplying the engine weigh six tons each. No experience or test equipment was available on the design and flow tests of such valves, and much of the development had to be done as part of our program. We now have in operation three engine test positions and a special test stand for testing of the thrust chamber. When delivery of production engines begins, next year, we will require additional test

positions for checkout and calibration firings, and for that purpose, three new test stands are now under construction. Additional manufacturing space is being provided at the contractor's home plant to enable him to make and deliver the quantities of F-1's which our plans require.

Program Status

The F-1 Engine development program has an impressive list of accomplishments. A year after the contract was signed full-scale components were undergoing tests, and in 27 months complete engine systems testing had begun. Full thrust and full duration tests have become routine. The engine has been gimbaled during hot firing. We expect successful completion of the Preliminary Flight Rating Tests this year.

By the end of this year F-1 engines will be delivered to MSFC and will be committed to ground testing for the booster stage of the SATURN V. Delivery of production engines for the early development flights of the SATURN V will begin early next year; development of the engine will continue through this entire period and beyond to increase the reliability to meet the requirements for manned flight.

The development program for this engine is going through the same characteristic technical phases which were experienced on other (Redstone, Jupiter and SATURN I) engine development programs. The areas which have required particular emphasis thus far have been subject to straightforward engineering solutions. Let me illustrate with three examples.

Early in the program, we found that to build the large thrust chamber, new manufacturing techniques had to be found. The large number of tubes which make up the chamber are held together by brazed metal, and it proved difficult to obtain the uniformity and quality which was needed. The manufacturing experts at Marshall worked closely with the contractor to develop a brazing process which has eliminated the need for expensive and time-consuming handbrazing of these chambers.

As a second example, about a year ago a series of malfunctions occurred on the turbopump test stand where the pump was being tested as a component to measure and improve its performance. An analysis was made which included not only the basic turbopump, but also the test stand and the procedures used in performing the tests. The cause of these malfunctions was found to be the formation of gas bubbles in the facility pipes which supply liquid oxygen to the pump. After some changes were made in the supply lines and the operating procedures were modified, testing was successfully resumed.

My third example is what is commonly known as the combustion instability phenomenon. When design of the F-1 was begun in 1959, combustion instability was known to be a potential problem. Accordingly, early in the program tests of various injectors for the thrust chamber were conducted, and a design was selected which had not experienced unstable combustion. For about a year, from mid-1961 to mid-1962,

engine tests were conducted without this phenomenon occurring. Then, on June 28 of last year we were testing development engine #008 on the test stands in California. A test run which was scheduled for the full 2 1/2 minutes running time was interrupted after 106 seconds of satisfactory performance by a rupture of a valve casting. The rupture was traced to combustion instability. Since this occurrence, several cases of combustion instability have taken place.

This phenomenon is not unique to the F-1, but has occurred in the development of most liquid rocket engines. Under certain conditions, vibrations can start which grow to such magnitude that rupture and internal erosion may occur. In some cases, we have found that vibrations in the propellant feed system influence the thrust chamber oscillations.

We are presently concentrating on combustion instability and are making progress. With the contractor at Rocketdyne, we have made an exhaustive survey of all test data having a bearing on the problem. Additional injectors have been built. This hardware is now in testing. Effort has been made to isolate those oscillations which take place in the propellant feed lines, and progress here is encouraging.

To summarize, the F-1 Engine development over the last four years has made satisfactory progress. The engine start and ignition problems which caused us so much trouble on the Pratt & Whitney engines for the S-IV stage have been non-existent on the F-1, and the engine shows an almost perfect record of starts and shutdowns. The individual components, such as valves, gas generator, and turbopump, have progressed satisfactorily.

The many tests have indicated that we will have a sound engine available when we need to begin our first stage flight tests. The maturity of the engine at this time is such that with the emphasis we are now putting on the remaining development tasks, we shall meet the requirements of the SATURN-APOLLO Program.

CONCLUSION

In this statement we have covered the status, launch plans, and flight missions of the three SATURN vehicles - SATURN I, SATURN IB, and SATURN V - which will perform vital roles in meeting the objectives of Project APOLLO.

We have discussed the current status of the stages, instrument units and engines that comprise each of these vehicles, including contractor and government effort, facilities, test programs, and production schedules.

We have described the current status F-1 Engine program.

We have seen that we are progressing satisfactorily in all areas of our programs, and that, despite the magnitude and technical complexities of the task, we are still on schedule to meet the established objectives of the National Space Program.

Thank you for the opportunity to appear before the subcommittee.

LIST OF SLIDES

Used by Dr. Wernher von Braun

Marshall Space Flight Center

Before the

Subcommittee on Manned Space Flight
Committee on Science and Astronautics
House of Representatives

1. SATURN I (Block II) Characteristics
2. SATURN I Booster
3. S-I Stages in Assembly at Marshall Space Flight Center
4. Thrust Structure for First Chrysler-Produced Stage
5. SATURN I Second Stage
6. S-IV Production at Douglas
7. S-IV Battleship Vehicle Test at Sacramento Test Facility
8. Hoisting S-IV Dynamics Vehicle in Marshall Dynamic Test Tower
9. Receipt of S-IV Test Vehicle at AMR
10. SATURN I Instrument Unit During Fabrication
11. Micrometeoroid Satellite Mission for SATURN I Vehicles SA-8/SA-9
12. Chrysler Area of Michoud Operations
13. Sacramento Test Facility
14. Launch Complex 37A/37B
15. SATURN IB Characteristics
16. SATURN IB First Stage
17. SATURN IB Second Stage
18. S-IVB Static Test Facilities at Sacramento Test Facility

19. SATURN V Characteristics
20. SATURN V First Stage
21. SATURN V First Stage Gore Segment Weld and Trim Fixture
at Marshall
22. Boring Mill at Michoud
23. SATURN V Second Stage
24. SATURN V Second Stage Bulkhead and Mockup Skirt Assembly
25. SATURN V Third Stage
26. SATURN V First Stage Static Test Facility
27. SATURN V Dynamic Test Tower
28. MSFC Michoud Plant
29. MTF And Michoud Facilities Vicinity Plan
30. Seal Beach Facility
31. Servicing SATURN V at Launch Complex 39
32. F-1 Engine